Center Innovation Fund: JPL CIF

Simplified laser frequency stabilization using spatial-mode interference

Completed Technology Project (2012 - 2012)

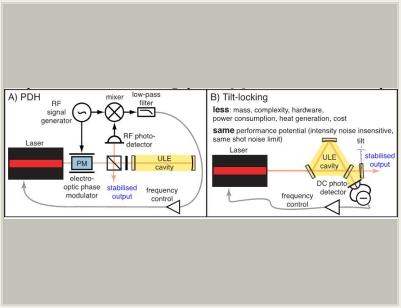
Project Introduction

We will demonstrate a laser frequency stabilization technique based on spatial-mode interference that promises reductions in complexity, mass and power consumption compared to the pervasive RF technique. Laser stabilization is an enabling technology for space-based laser interferometers and high-performance laser metrology systems, with applicability to missions such as an optical follow-on to GRACE. Successful demonstration of this technique will simplify laser frequency control in space.

The readout technique for "tilt locking" has been widely adopted in a range of scientific areas from quantum optics to spectroscopy since first being demonstrated in 1999 [1,2], but it has not been applied to high-performance laser frequency stabilization. Common laser stabilization systems transfer the length stability of an optical reference cavity to the laser frequency (or wavelength) using the standard RF interrogation technique (Pound-Drever Hall (PDH) locking), which employs electro-optic phase modulation of the carrier and RF demodulation as shown in Figure A below. In tilt locking, the reference signal relies instead on interference between overlapping spatial modes on reflection from the cavity, realized simply by intentionally tilting the laser beam and reading out a DC signal level difference between two halves of a two-element photodiode. The use of this DC signal allows the elimination of the phase modulator, RF signal generator and mixer electronics, as shown in Figure B. In addition, the DC operation largely reduces the susceptibility to a commonly limiting noise source: parasitic etalons. To demonstrate tilt-locking as a viable laser frequency stabilization technique we will construct a tilt-locking system comprising a laser, an ultra-stable optical reference cavity in vacuum, along with associated optics and electronics. [1] D. A. Shaddock et al. Opt Lett 24 1499 (1999) [2] B. J. J. Slagmolen, et al. IEEE J. Q. E., 38, 11, (2002)

Anticipated Benefits

Development of the tilt locking technique through this project can be seen as a risk reduction for the laser ranging package on the GRACE Follow-On mission, which will use the PDH technique for laser frequency stabilization. For missions like GRACE Follow-On, which are already complex, the simplicity of the tilt locking system is also a key attribute that is desirable.



Project Image Simplified laser frequency stabilization using spatial-mode interference

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Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Jet Propulsion Laboratory (JPL)

Responsible Program:

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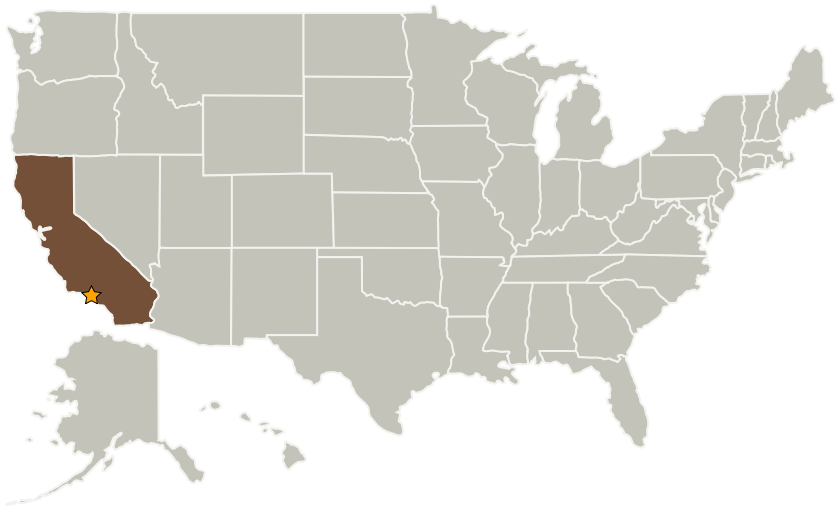
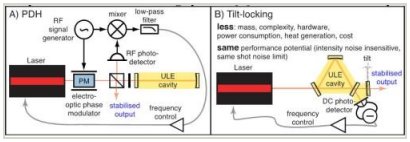
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Jet Propulsion Laboratory(JPL)	Lead Organization	NASA Center	Pasadena, California

Primary U.S. Work Locations
California

Images



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Project Image Simplified laser frequency stabilization using spatial-mode interference
(https://techport.nasa.gov/image/1166)

Project Management

Program Director:
Michael R Lapointe

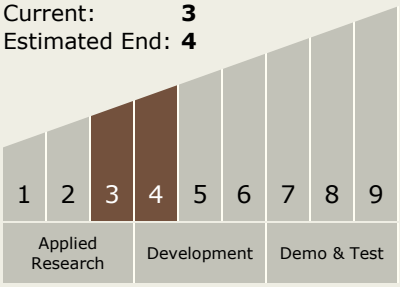
Program Manager:
Fred Y Hadaegh

Project Manager:
Jonas Zmuidzinas

Principal Investigator:
Kirk Mckenzie

Technology Maturity (TRL)

Start: **3**
Current: **3**
Estimated End: **4**



Technology Areas

Primary:

- TX05 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
  - TX05.1 Optical Communications
    - TX05.1.6 Optimetrics